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NRL REPORT 4136

LABORATORY TESTS OF SOME OF THE POPULAR AUDIO AMPLIFIERS

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April 29, 1953



NAVAL RESEARCH LABORATORY
WASHINGTON, D.C.

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ABSTRACT

Sine-wave frequency response at full- and low-power and square-wave test results are shown for many of the commonly used high-fidelity audio amplifiers. These results are given in a uniform manner for comparison purposes.

PROBLEM STATUS

This is a final report on this phase of the problem; work is continuing on other phases.

AUTHORIZATION

NRL Problem R10-57
RDB Project NR 510-570

Manuscript submitted March 16, 1953

LABORATORY TESTS OF SOME OF THE POPULAR AUDIO AMPLIFIERS

INTRODUCTION

Tests were made by the Instrumentation Section of the Sound Division, Naval Research Laboratory, on some of the more popular audio amplifiers. These tests were made for the following reasons:

1. Several unusually good amplifiers are needed by the Sound Division (and by other Naval activities) for calibration and test work.
2. The tendencies toward lower frequencies in sonar research and toward higher frequencies in high-fidelity audio amplifiers result in an overlap in these frequency ranges. This overlap makes many of the high-fidelity audio amplifiers extremely useful in sonar research.
3. There is a considerable demand for information about high-fidelity audio amplifiers. The demand has not been satisfied by manufacturers' literature, since this literature is not uniform for comparison purposes, and has sometimes been presented in misleading ways.

GENERAL SCOPE

The information given here consists mainly of frequency-response curves plotted at full power and at 0.10-watt output into a pure-resistance load. Extreme low-frequency response is not shown, because of its relative unimportance in sonar work and because of the increased difficulty in making measurements below 20 cycles.

Square-wave responses are also shown at approximately full power and at a 0.10-watt output into a pure resistance load. Square-wave responses are shown generally at 0.1, 1, and at 10 kc. In some amplifiers where these seem to be insufficient, other frequencies are included.

In particularly promising amplifiers, adjustments were made in the feedback circuit and/or in compensating circuits to improve the performance. It has not been determined whether these alterations would always be desirable for other chassis layouts or other transformers of the same type and manufacturer. In a great many cases, it seemed that low-frequency stability was inadequate in the Williamson amplifier circuit. Practically all Williamson amplifiers tested showed a tendency to "ring" at about two or three cycles.

This tendency was eliminated in all cases by changing the values of the coupling capacitance in the grid circuit of the output tubes from 0.25 mfd to about 0.02 mfd. The low-frequency response was not in any case seriously affected by this change. In some instances, to improve high frequency response, it was found desirable to eliminate the r-c compensating network in the plate circuit of the first amplifier tube, in the Williamson circuit. The addition of a fairly high value resistor in series with the grid of the input stage was found desirable on some Williamson amplifiers. In some cases, adjustment for optimum value of capacitance, in parallel with the feedback resistor, was necessary.

In all cases, harmonic distortion was considered low enough to be negligible for the specific uses in mind. In some cases, however, distortion was high at the extremes of frequency, where the output had fallen off. No quantitative distortion measurements or phase shift measurements are included in this report. No listening test results are included. Critical listening tests and other measurements not included herein might influence the selection of these amplifiers.

DISCUSSION OF INDIVIDUAL AMPLIFIERS

McIntosh Amplifiers¹

Output transformers for McIntosh amplifiers are not available separately; therefore, it is not practical to construct these amplifiers from basic components.

a. The 20-watt McIntosh Model 20-W2 amplifier (Figure 22*) seemed to be the best general purpose high-fidelity amplifier under the conditions of these tests (Figure 1). It is essentially the 15-watt amplifier originally introduced by McIntosh Laboratories and rerated by the manufacturer to 20 watts. It was found when making the tests that distortion increases rapidly above about 18 watts and therefore the data shown was taken at 18 watts.

The extremely wide and smooth frequency characteristics of these amplifiers, and their small size, high efficiency, and good reliability show them to be much better than any others tested here.

b. In the 50-watt McIntosh amplifier (Figures 23 and 24), as might be expected, some sacrifice was made in other characteristics to obtain higher power (Figure 2). The frequency range is not so wide as for the 20-watt amplifier; however, the square-wave response is nearly as good. The over-all efficiency is somewhat better than for the smaller model. The full 50-watts output is available without any sharp increase in distortion.

Some difficulty has been encountered with 6L6 tubes in this amplifier. The use of Type 5881 tubes solved this problem and makes the amplifier very reliable.

c. The 150-watt McIntosh amplifier, Model K-100 (Figure 25), again makes a sacrifice in other performance to obtain higher power, as indicated by the data shown here (Figure 3). Its size however is only slightly larger than that of the 50-watt model. The full 150 watts are available without any sharp increase in distortion. This amplifier

¹ For a general discussion of McIntosh amplifiers, see Frank H. McIntosh and Gordon, J. Gow, "Description and Analysis of a New 50-Watt Amplifier Circuit," *Audio Engineering*, 33, No. 12:9-11, 35-40, December 1949

* All figures are in Appendix

has been superseded by a 200-watt model, but we have no information on the latter at present.

Williamson Amplifiers²

Several amplifiers using the Williamson circuit (Figure 26) were tested. Some were constructed from basic components, some were constructed from kits, some were commercial models.

- a. One of the most popular transformers in this country for the Williamson amplifier is the Peerless S-265-Q. The data presented here (Figure 4) indicates why this is so. With properly adjusted feedback and frequency compensation, it is practically flat out to 200 kc at low levels, and at full power is only 2 db down at 100 kc. Note the square-wave response at 20 kc.
- b. The Peerless S-270-Q transformer is as nearly as possible similar to the S-265-Q transformer except that the secondary is wound for 62.5 to 500 ohms. This high impedance makes it much more useful for many purposes. The frequency response (Figure 5) is not as good as the S-265-Q, presumably because of the increased effect of stray capacitance at the higher impedance. The secondary was used unbalanced in order to satisfy the feedback requirements. For balancing the 250- and the 500-ohm output—providing the 62.5- and the 125-ohm outputs were not desired—a better arrangement would probably be to ground the center of the secondary and to take the feedback from one-half of the secondary.
- c. The Partridge WWFB/1.7 transformer, made in England but widely used throughout the world, was used in the original amplifier by Williamson. It performs extremely well (Figure 6) and is slightly less expensive delivered in this country than the Peerless transformers. The feedback and compensation were adjusted for optimum square-wave response for the measurements shown. Note the extreme high-frequency response and the excellent rise time at low power. Amazing square-wave response at low power was obtained as high as 70 kc. Sine-wave response was flat down to 10 cycles. The 100-cycle, square-wave response, however, indicates that the low-frequency response is only comparable with the best of the other good high-fidelity amplifiers.
- d. The Partridge CFB/1.7 transformer, also made in England, was tested in the General Radio circuit as well as in the Williamson circuit.³ Its performance was poor under both conditions. The data on this transformer in the Williamson circuit is given in Figure 7. This transformer was almost a complete failure in the General Radio circuit; therefore the data is not given. This failure was very disappointing, since this transformer was presumed to be as good as the Partridge WWFB/1.7, and has a higher power rating.
- e. The Audio Development Co. 314E transformer in the Williamson circuit showed a remarkable low-frequency response at low power (Figure 8). The high-frequency response was relatively poor. Extreme overshoot on square waves was observed as low as 100 cycles.

²

D. T. N. Williamson, "Design for a High-Quality Amplifier," *Wireless World*, 53:118-121, 161-163, April and May 1947. D. Sarser and M. C. Sprinkle, "Musician's Amplifier," *Audio Engineering*, 33, No. 11:11-13, 53-55, November 1949

³

A. P. G. Peterson, "A New Push-Pull Amplifier Circuit," *General Radio Experimenter*, 26, No. 5:1-7, October 1951

f. The Stancor A-8054 transformer performed remarkably well (Figures 9, 10, 27), considering its price, which is approximately \$10.00. The particular unit used in this test, as supplied by the manufacturers and used in their circuit, performed well. However, the square-wave response was improved by adding 300 micromicrofarads in parallel with the feedback resistor, and about 50,000 ohms in series with the grid of the input tube. This has only a slight effect at full power and eliminates the sharp peak which causes square-wave response "ringing."

g. The Williamson Amplifier commercially built by Radio Craftsmen, Inc., (Figure 28) performed very well "as is" (Figure 11). It is not quite as smooth on high-frequency response and transient response as the same circuit using the Peerless S-265-Q transformer. However, the performance is better than that of the amplifier with the Stancor transformer. High quality workmanship, high quality components, and its good performance justifiably make it a popular amplifier.

The "Ultra-Linear" Circuit

This circuit⁴ as originally suggested by Acro Products Co. (Figure 29), was tested with the Acrosound TO-300 and the Peerless S-265-Q transformers; in each case, approximately double the output power of the Williamson circuit was obtained with only a slight effect on the frequency-response characteristic.

a. The Acro TO-300 transformer was used in the recommended circuit, and the results were, in general, good (Figure 12), but the sharp resonance at about 130 kc could not be removed by adjustment of feedback and compensation. A great number of methods of adjustment were tried without any significant success. Two of these transformers were tried in this and in other circuits. Other transformers were also tried successfully in this and other circuits. This definitely associates the resonance with the TO-300 transformers.

b. The Peerless S-265-Q transformer was tested in this circuit with very good success (Figure 13). The output power was approximately double that of the Williamson circuit and the frequency response was almost identical with the data given on this transformer in the Williamson circuit.

"Ultra-Linear" Version of the Williamson Circuit

Two different output transformers were tried in the "ultra-linear" version of the Williamson circuit.⁵ The effect was that the power output was approximately double that of the original Williamson amplifier with no noticeable increase in distortion or sacrifice in frequency response. This circuit shows some improvement, under the conditions of these tests, over the original ultra-linear circuit. David Hafler and Robert L. Keroes, of Acro Products Company, state in their letter to the editor (Audio Engineering, September 1952) that optimum performance of the ultra-linear Williamson amplifier circuit is not reached with the Peerless transformer. Even so, our tests showed that the performance with the Peerless S-265-Q transformer (Figure 14) was superior to the performance with

⁴ D. Hafler and H. I. Keroes, "An Ultra-Linear Amplifier," Audio Engineering, 35, No. 11:15-17, November 1951

⁵ D. Hafler and H. I. Keroes, "Ultra-Linear Operation of the Williamson Amplifier," Audio Engineering, 36, No. 6:26-27, 43-44, June 1952. D. Sarser and M. C. Sprinkle, "Gilding the Lily," Audio Engineering, 36, No. 7:13-14, 36-37, July 1952

the Acro TO-300 transformer (Figure 15). The superiority was in transient response, as was indicated in previous tests of the Acro TO-300 transformer in other circuits. Other characteristics tested here of the Peerless S-265-Q transformer in this circuit are about equal to the Acro TO-300.

The General Radio Single-Ended Push-Pull Amplifier

The General Radio circuit⁶ (Figure 30) shows some promise of an improvement over the circuits in general use.

The General Radio Type 942A transformer, when tested in the circuit, performed reasonably well (Figure 16) at 50-watts output with 6L6 tubes. However, tube life was short and balancing adjustments were difficult to make. It seems likely that operation at lower power would be more practical.

The Western Electric Type 124 Amplifier⁷

This circuit (Figure 31) using the Western Electric Type 171-C output transformer has been used to some extent by "audio fans." The data (Figure 17) shows it to be a fair amplifier but is no comparison, for instance, to the Stancor transformer in the Williamson circuit at a much lower price.

The H. H. Scott Type 221-H Amplifier

This amplifier (Figure 32) was tested (Figure 18) and found to be inferior in every respect to all other amplifiers tested and its price is approximately the same as for the McIntosh 20-watt amplifier.

The Audio Pacific Amplifier

This amplifier (Figure 33) was the only amplifier tested with built-in tone controls (Figure 19). It is hardly fair to compare it with the others. However, even with the tone controls adjusted for optimum square-wave response (Figure 20), its performance does not compare very favorably with the best of the other amplifiers tested.

The Fisher Model 50-A Amplifier

This amplifier (Figure 34) was somewhat of a disappointment inasmuch as about the only manufacturer's advertised specification which was met by the amplifier tested was its power rating (Figure 21). It will deliver the full 40 watts before any sharp increase in distortion. Frequency response and transient response were not good at either the high or the low frequencies.

⁶ Arnold Peterson and Donald B. Sinclair, "A New Push-Pull Amplifier," General Radio Experimenter, October 1951

⁷ CDR Charles W. Harrison, "High Fidelity Sound Systems," BuShips "Electron," December 1948. (Restricted-Security Information.)

REMARKS

In making tests of this nature, one soon reaches the point of making the difficult decision of just when to stop. It is felt that obtaining or building more amplifiers for tests would be passing the point of diminishing returns. Probably, further tests of the amplifiers included here would be beneficial for many purposes and this work will continue on a low-priority basis.

This report is not intended to present any new or original information, nor is it intended to be, by any means, a complete survey of the field, as new and better amplifiers are being introduced into the field at a rapid rate. This report is intended to present unbiased information that is uniform for comparison purposes on some of the present day high-fidelity amplifiers.

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APPENDIX
Response Curves and Circuit Diagrams

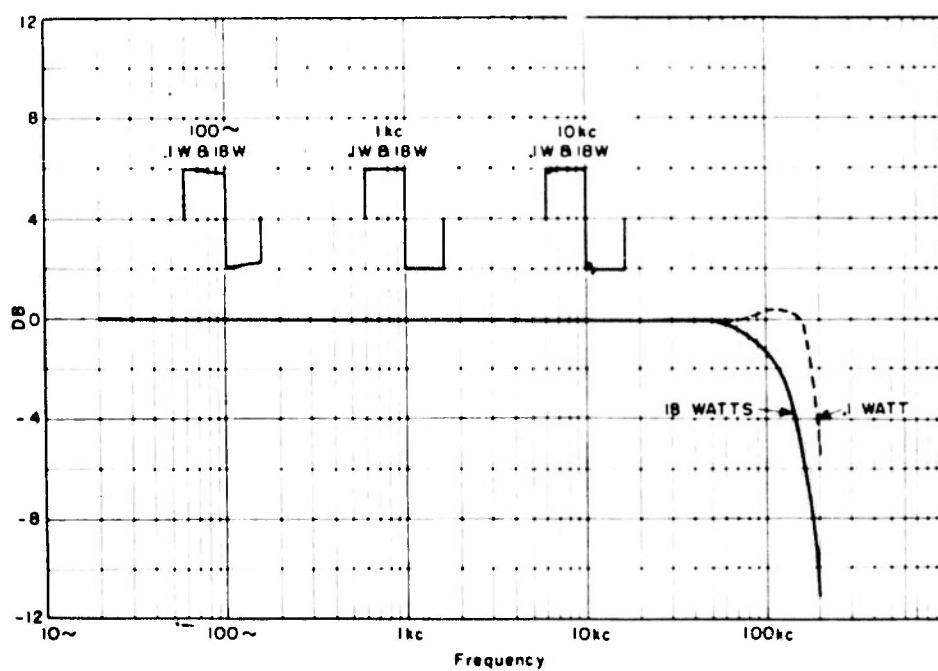


Figure 1 - McIntosh Model 20-W2

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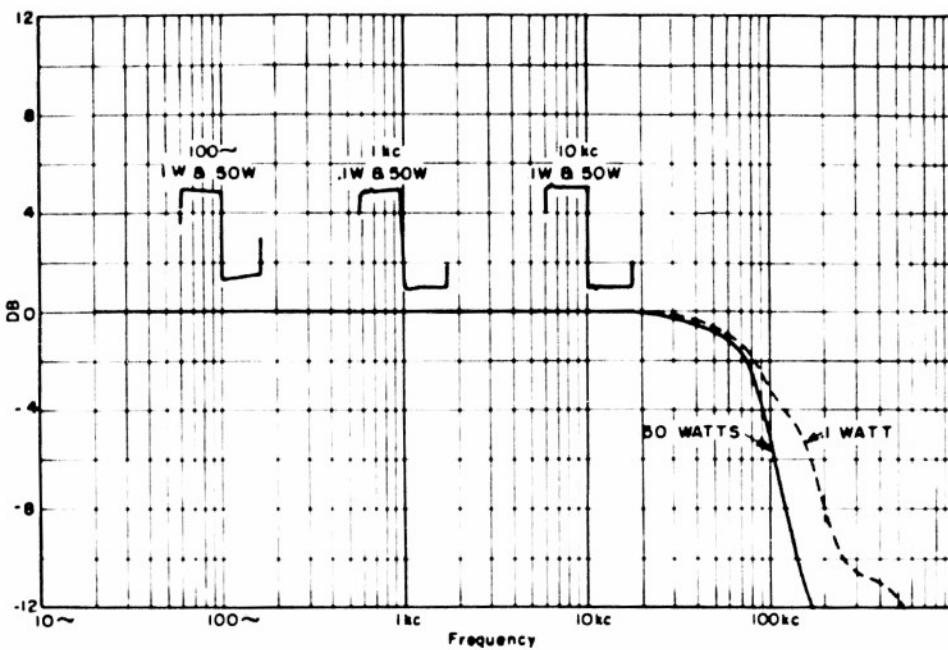


Figure 2 - McIntosh Model 50-W1

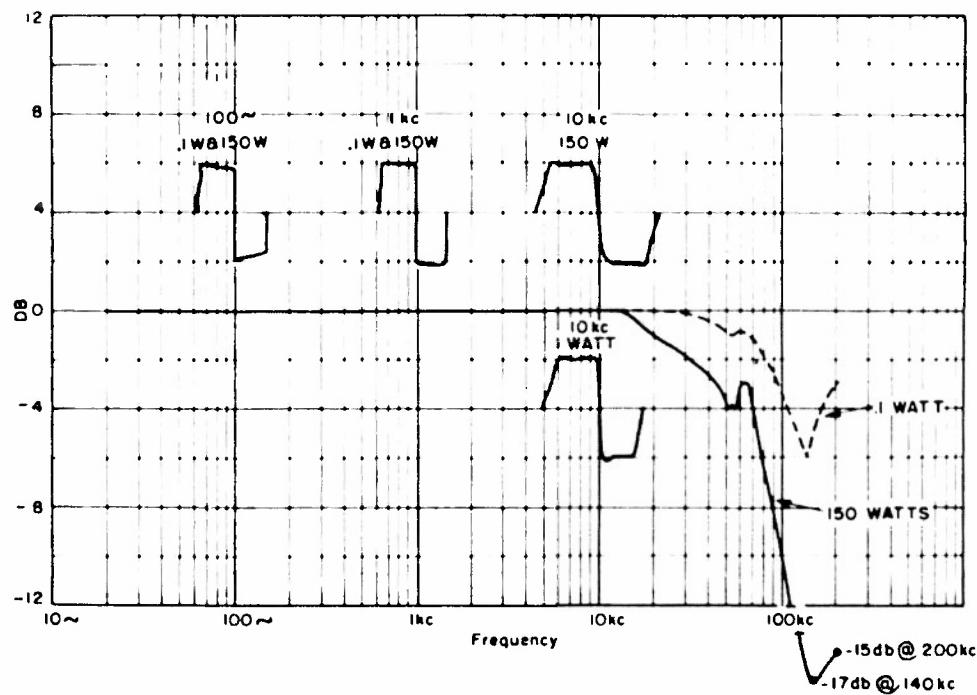


Figure 3 - McIntosh Model K-100

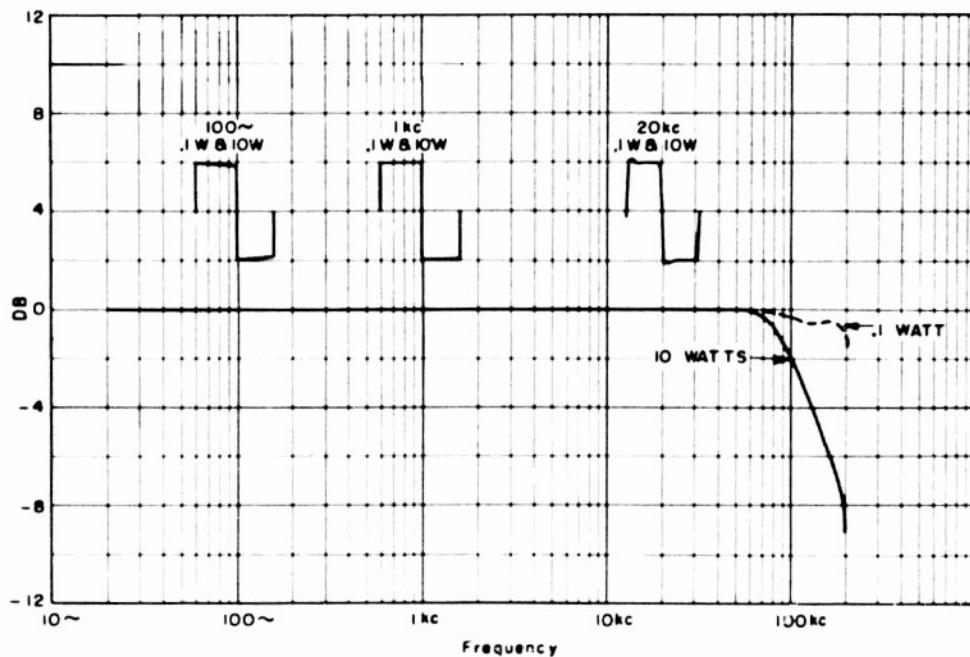


Figure 4 - Williamson circuit with Peerless S-265-Q transformer

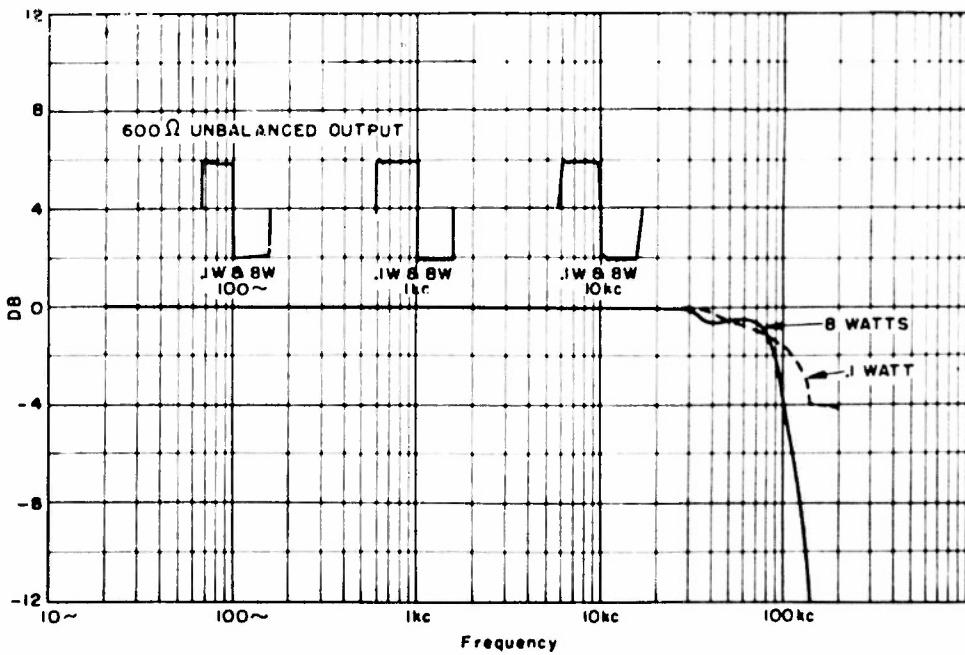


Figure 5 - Williamson circuit with Peerless S-270-Q transformer

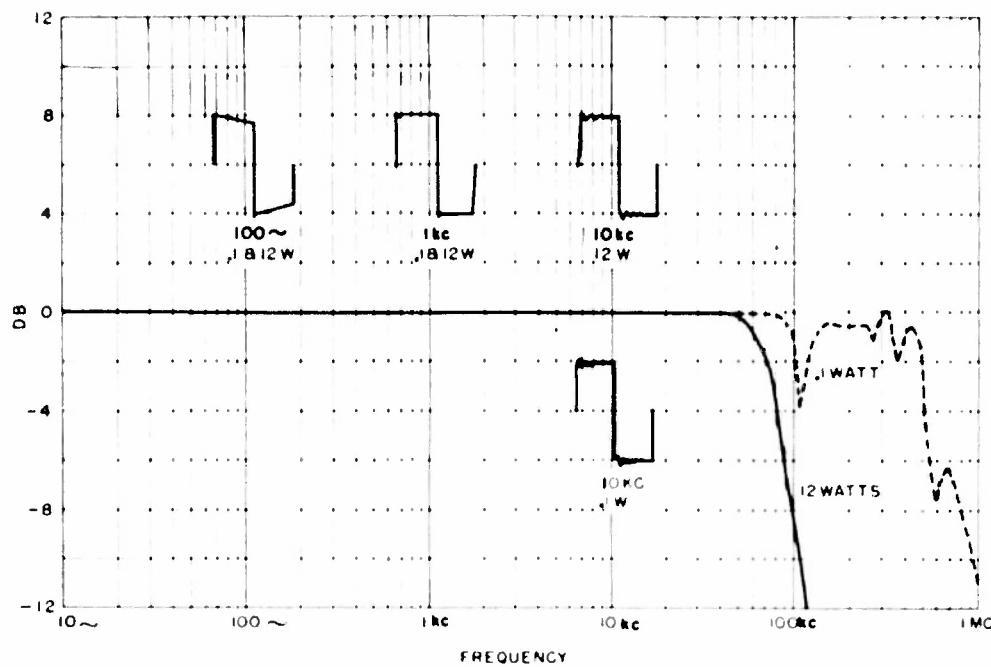


Figure 6 - Williamson circuit with Partridge WWFB/1.7 transformer

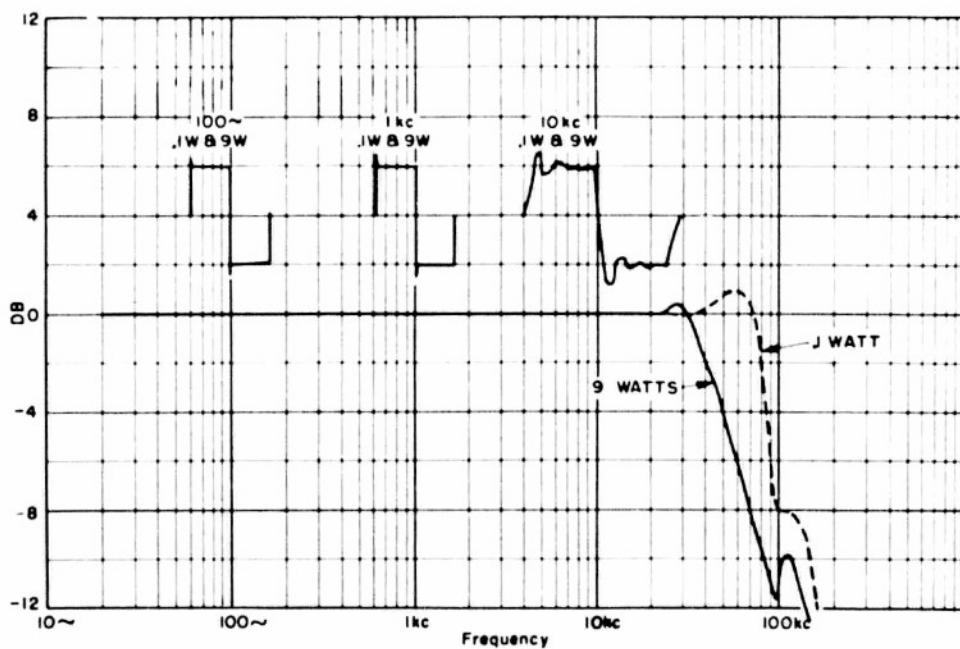


Figure 7 - Williamson circuit with Partridge CFB/1.7 transformer

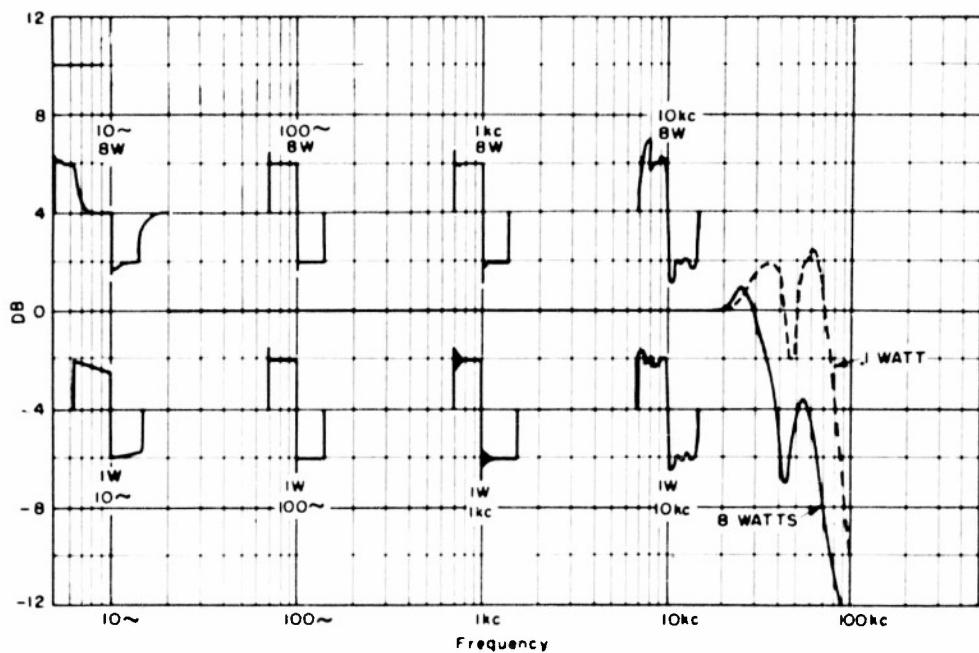


Figure 8 - Williamson circuit with Audio Development Co.
314-E transformer

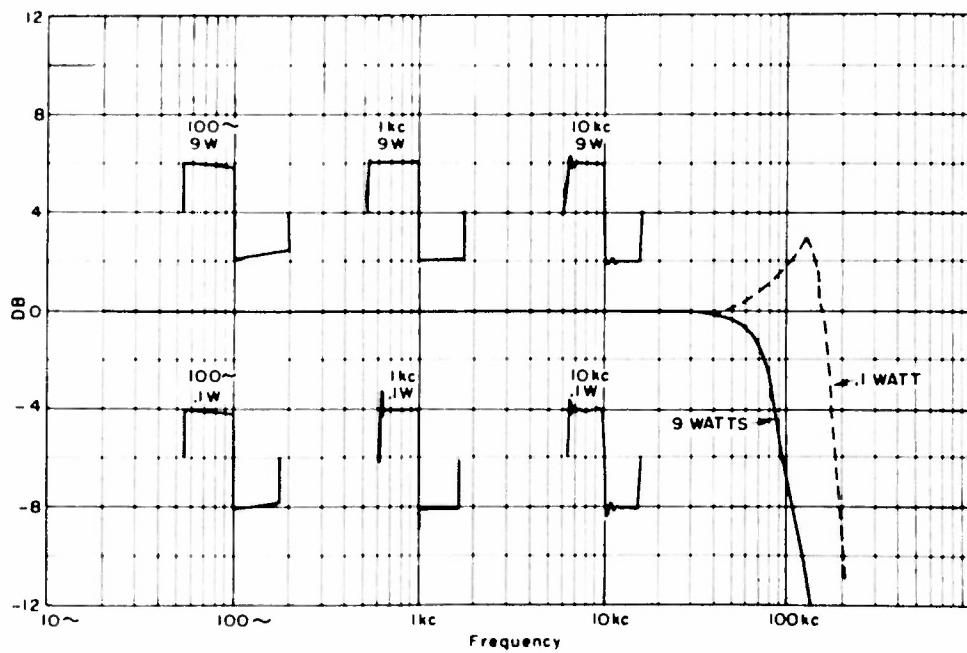


Figure 9 - Williamson circuit with Stancor A-8054 transformer
(with feedback as specified by Stancor)

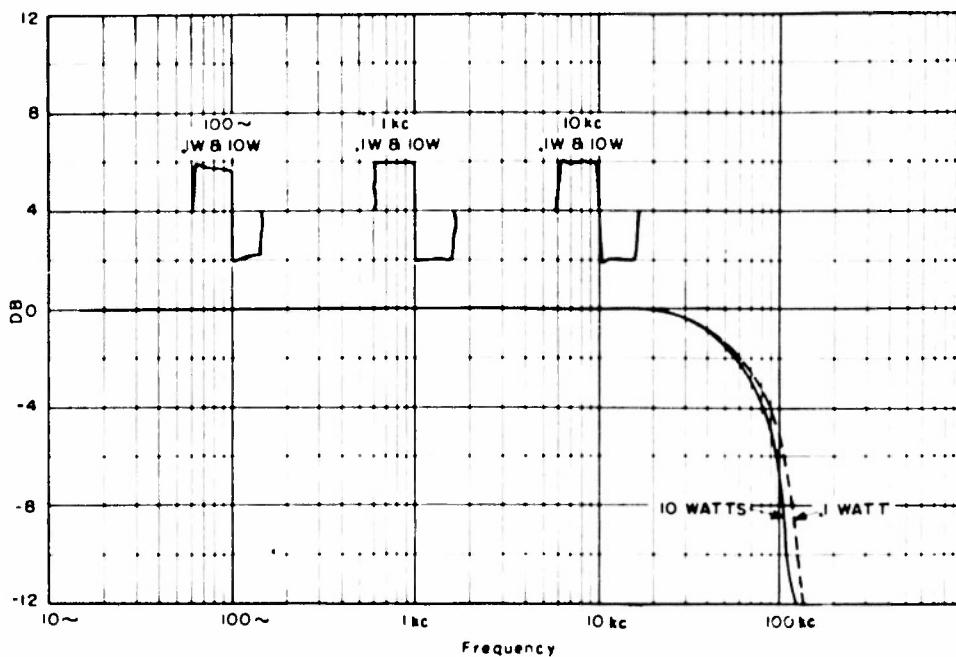


Figure 10 - Williamson circuit with Stancor A-8054 transformer
(after conversion)

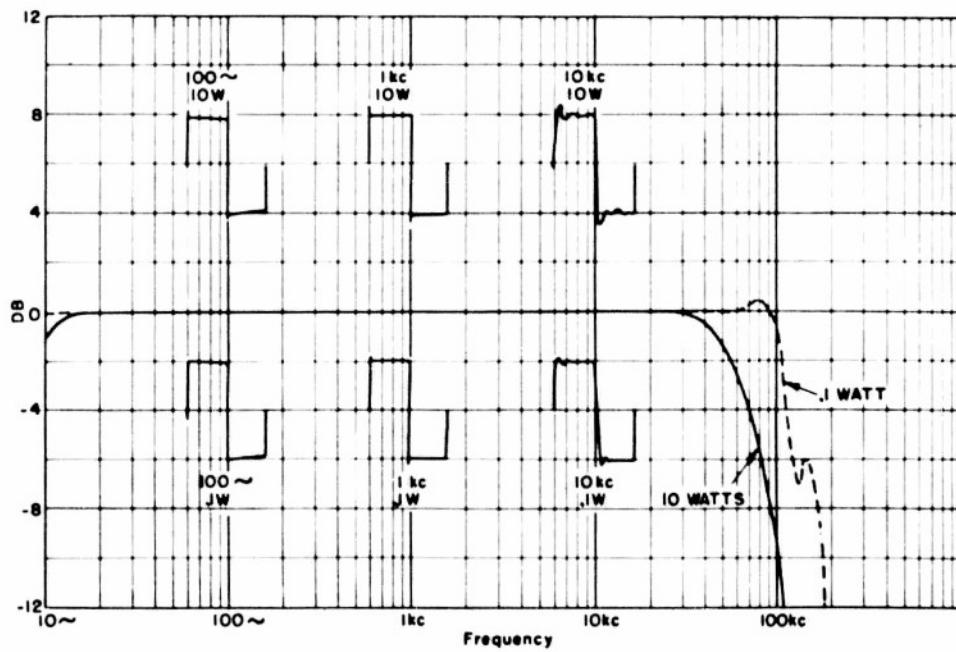


Figure 11 - Williamson circuit - Craftsmen Model 500

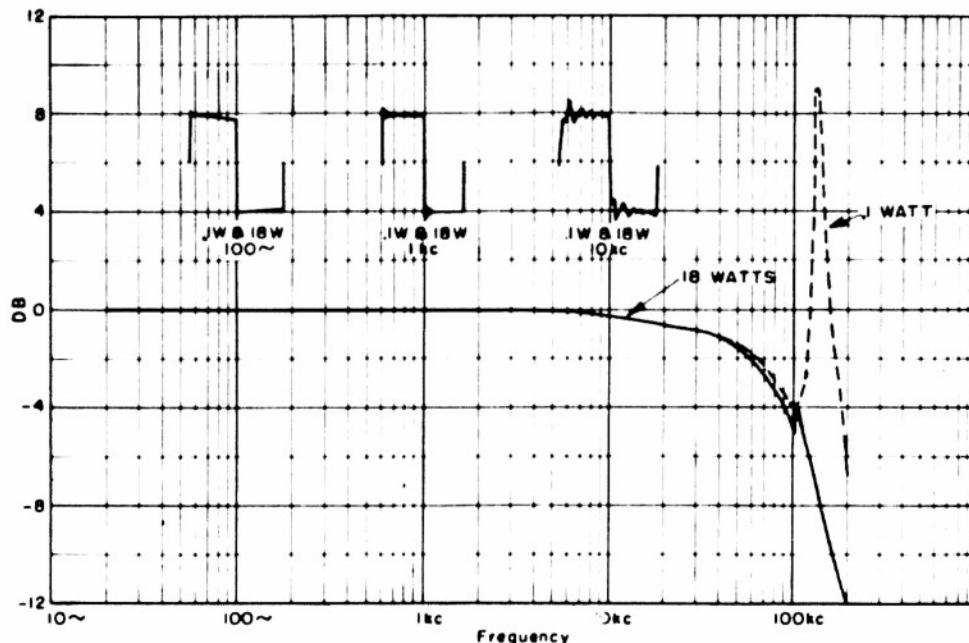


Figure 12 - "Ultra-Linear" circuit with Aerostar TO-300 transformer

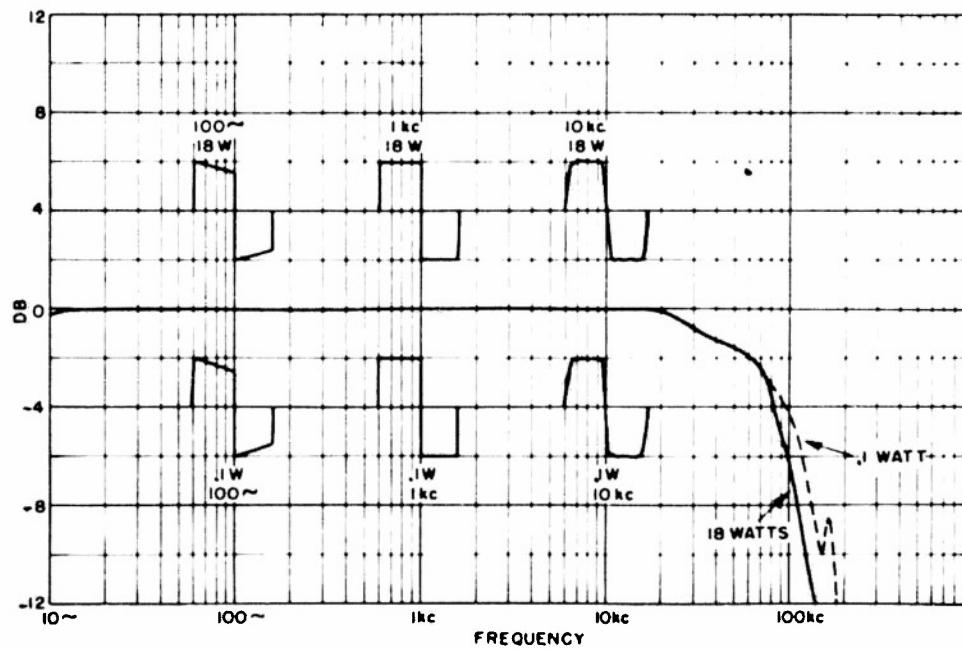


Figure 13 - "Ultra-Linear" circuit with Peerless S-265-Q transformer

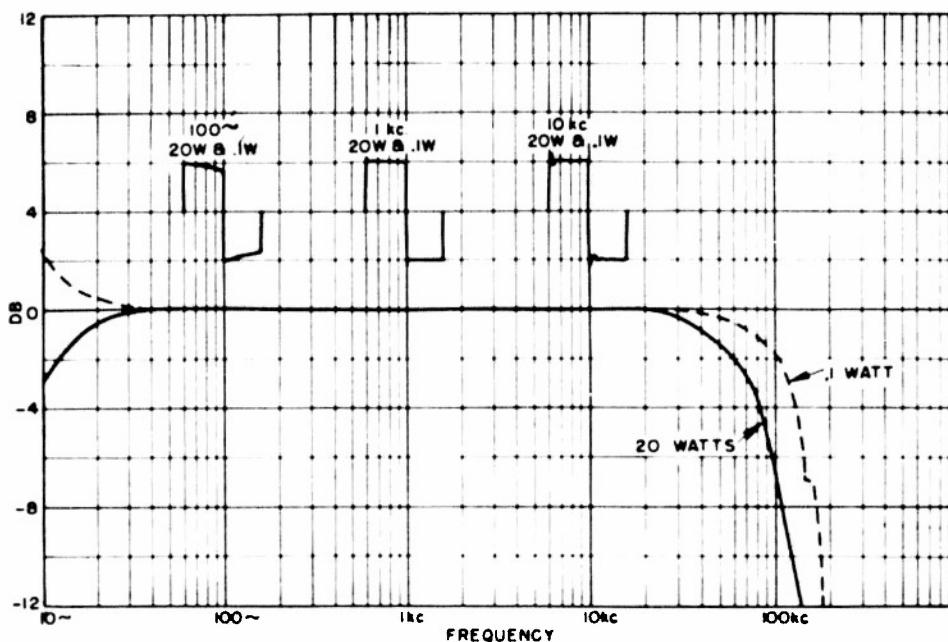


Figure 14 - "Ultra-Linear" version of Williamson circuit
with Peerless S-270-Q transformer

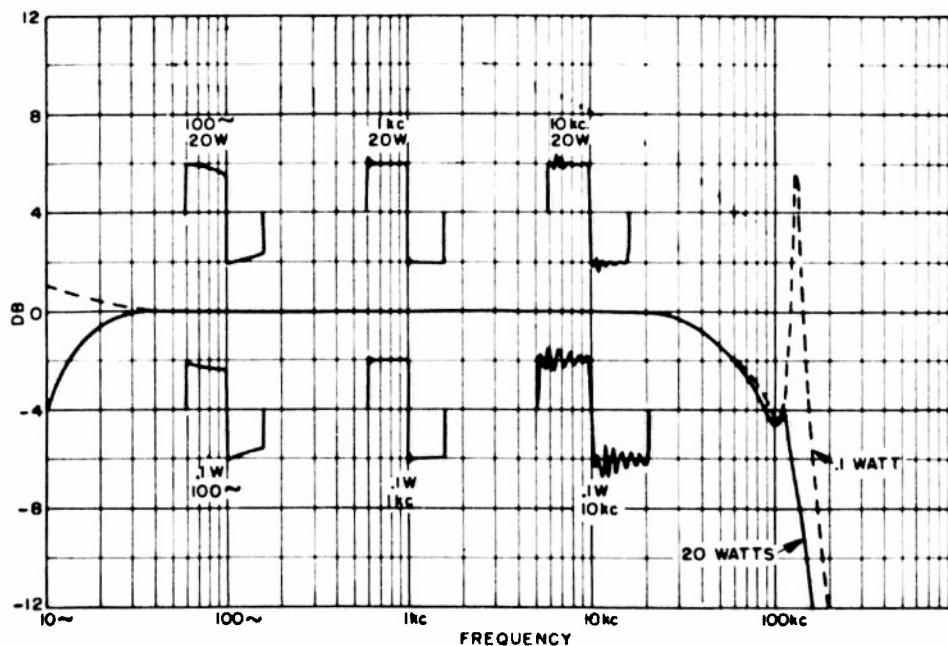


Figure 15 - "Ultra-Linear" version of Williamson circuit
with Acrosound TO-300 transformer

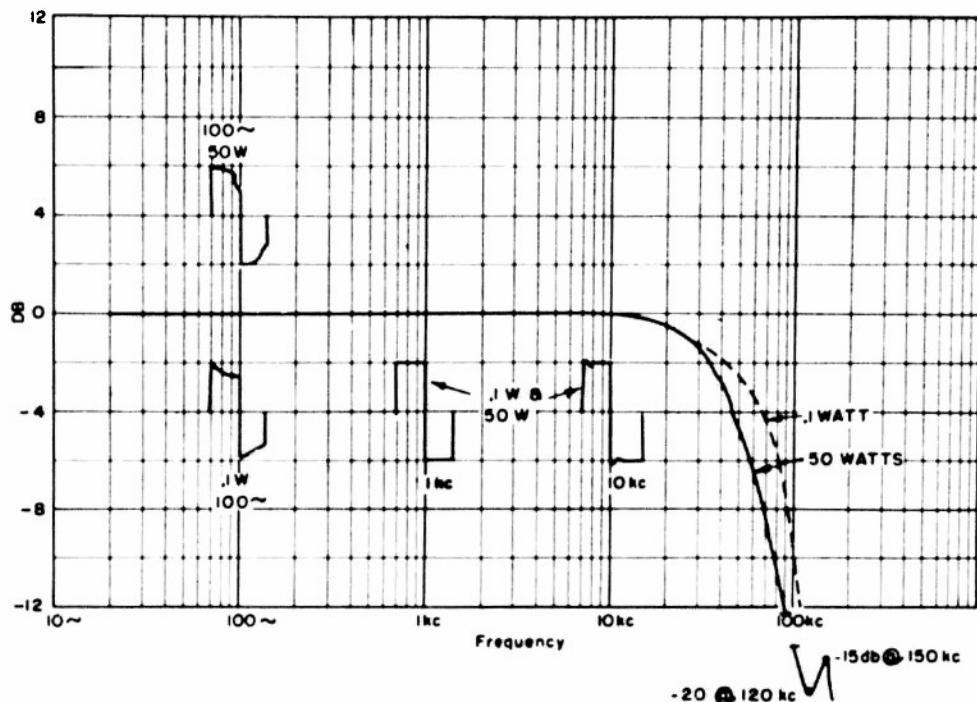


Figure 16 - General Radio single-ended, push-pull circuit
with General Radio 924-A transformer

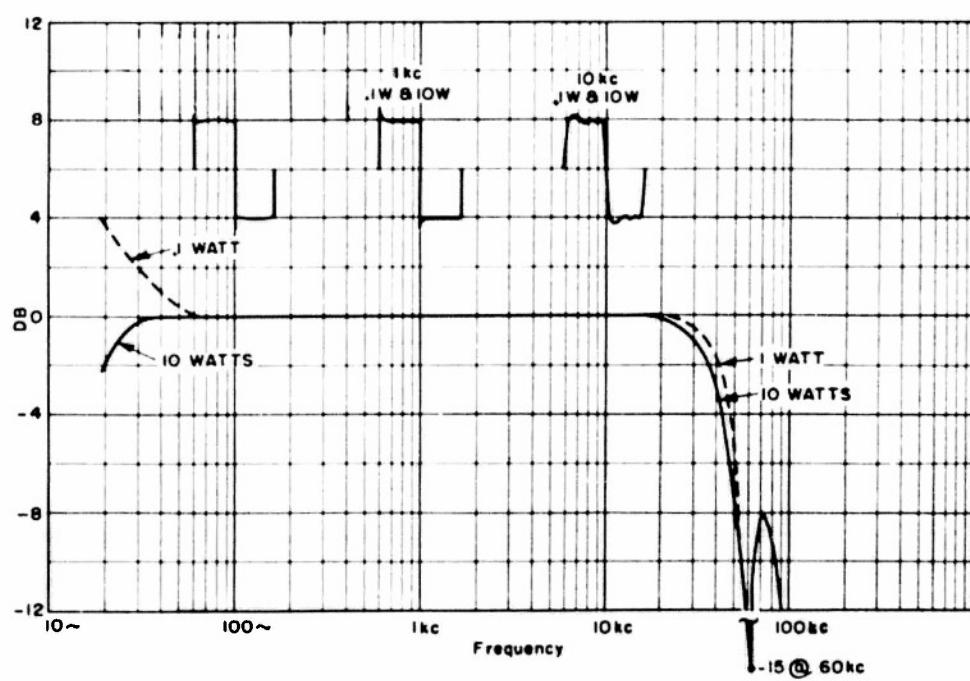


Figure 17 - Western Electric type 124 circuit

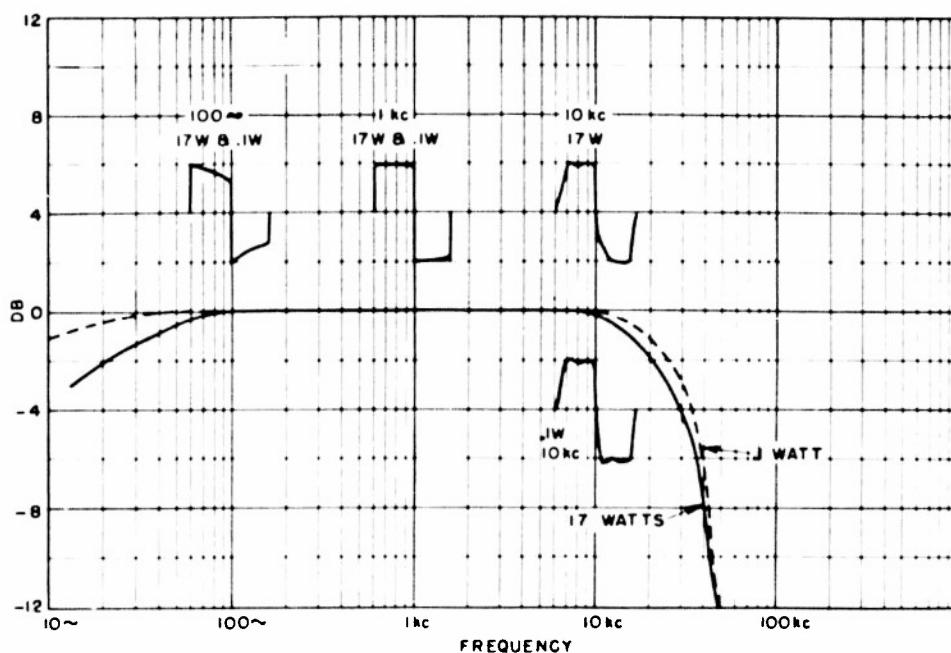


Figure 18 - H. H. Scott type 221-H

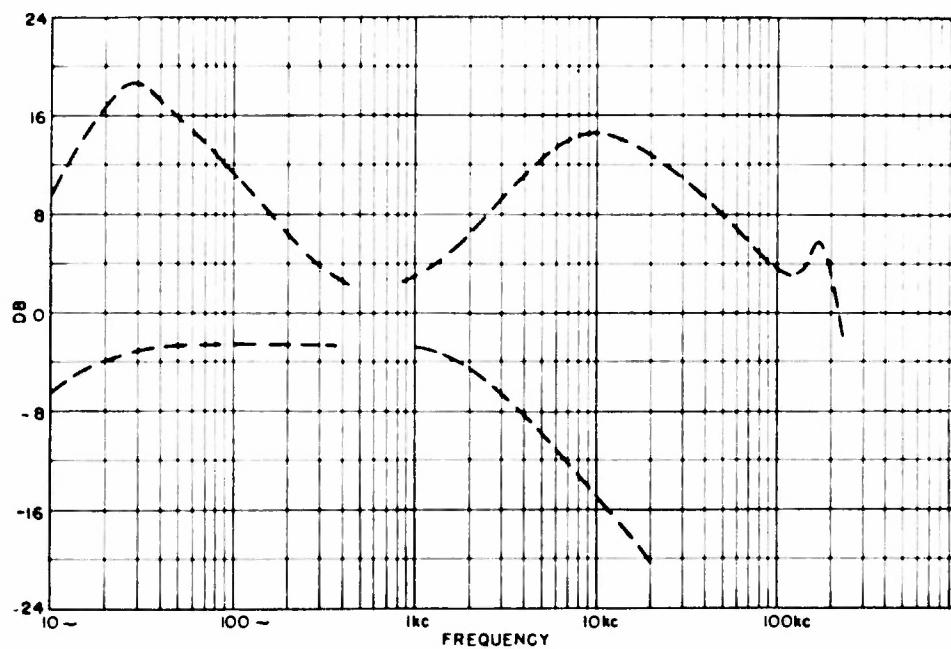


Figure 19 - Audio Pacific (at tone control extremes)

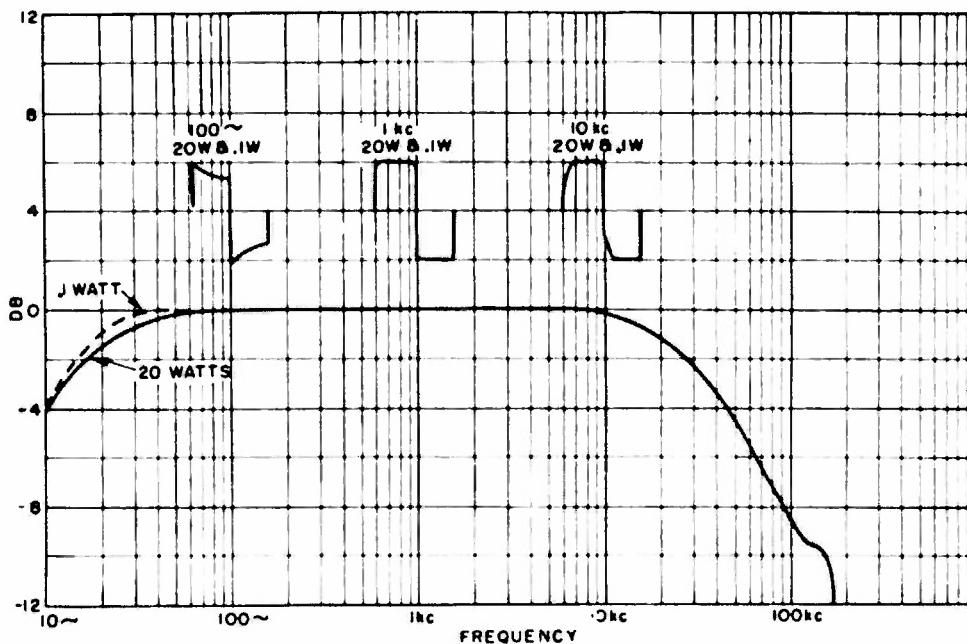


Figure 20 - Audio Pacific (with tone controls adjusted for optimum square-wave response)

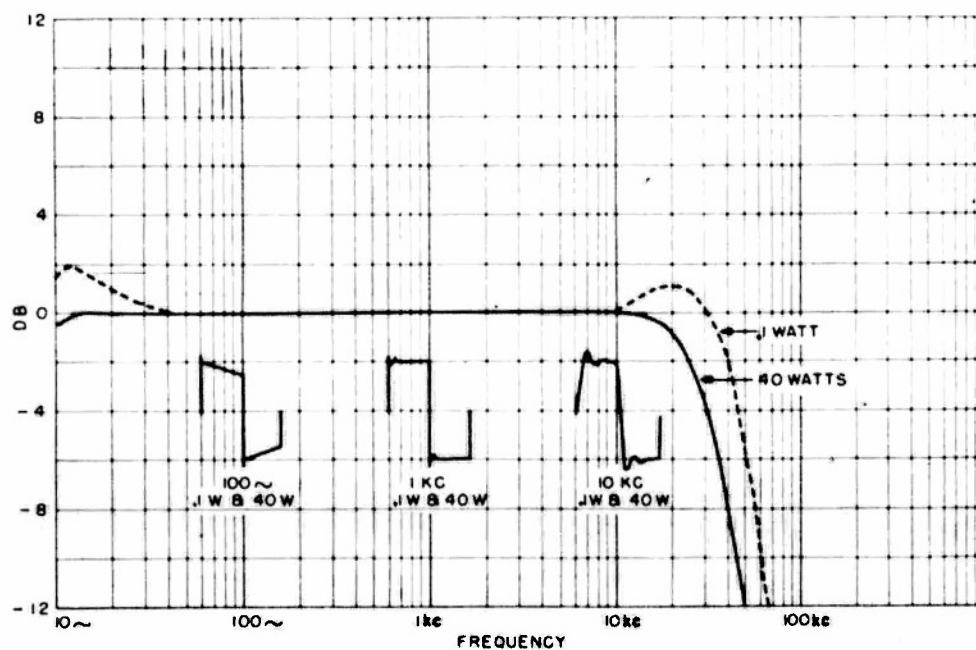


Figure 21 - Fisher Model 50-A

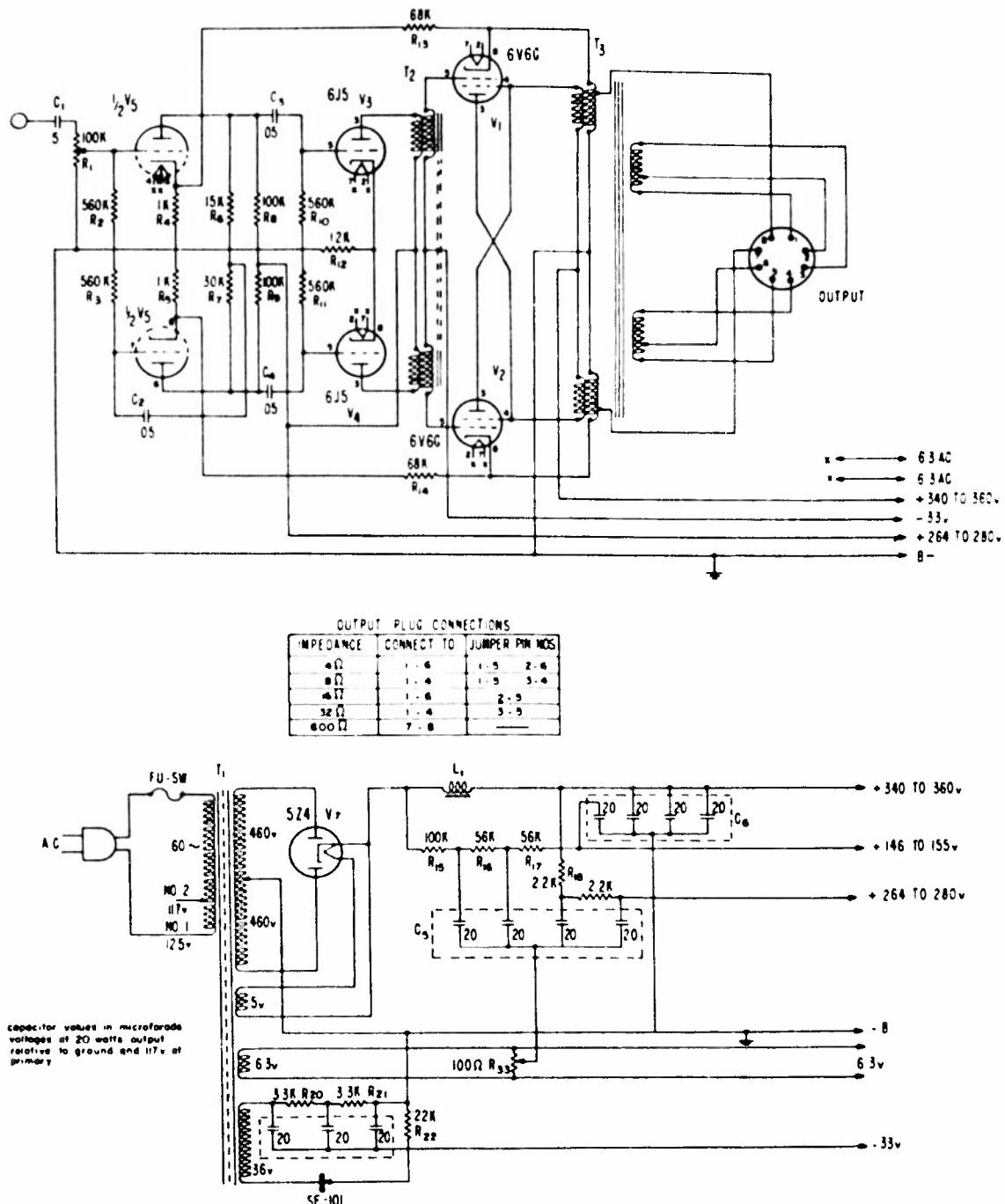


Figure 22 - McIntosh Model 20-W2

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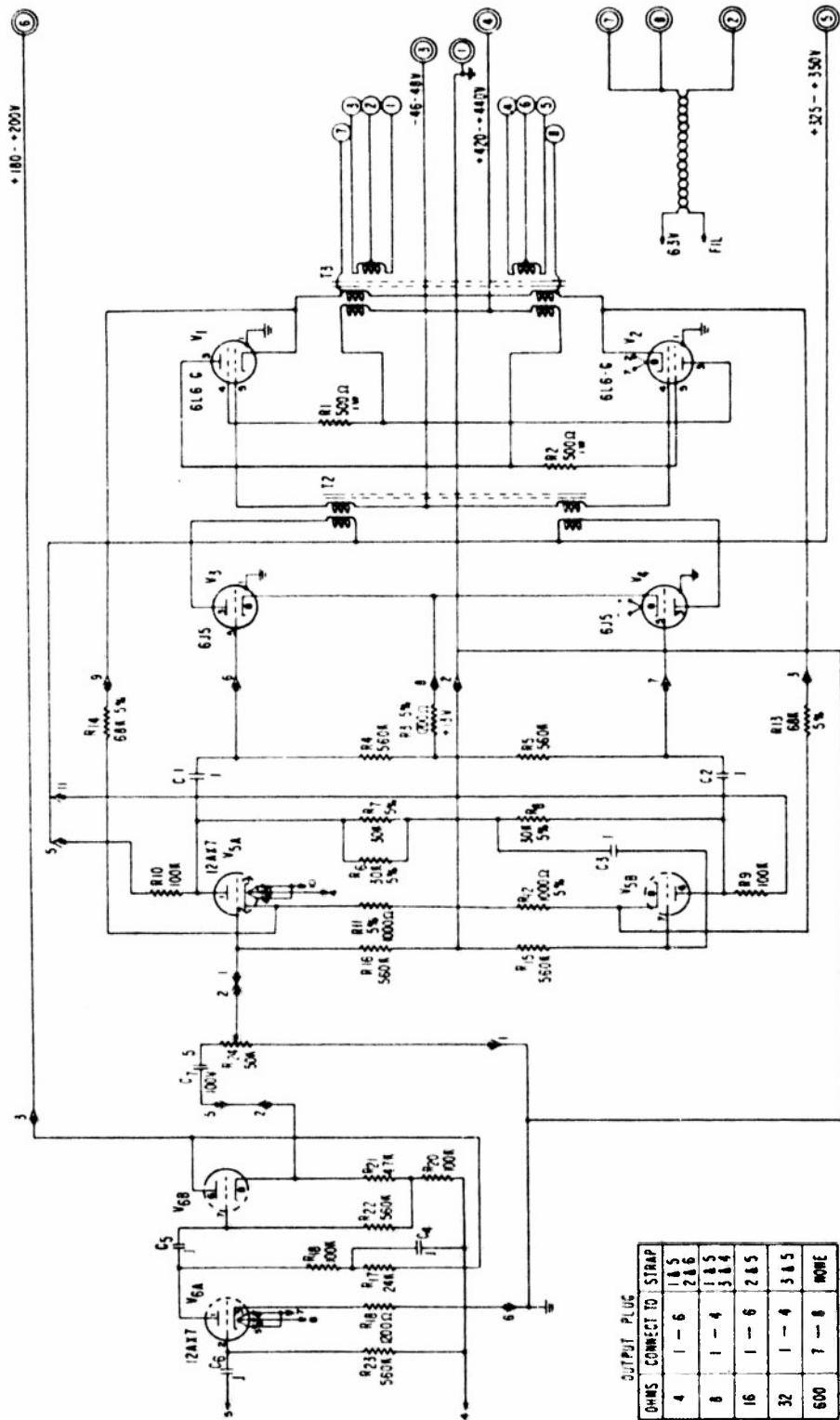


Figure 23 - McIntosh Model 50 - W1

ALL RESISTORS-10% SW AND
ALL CAPACITORS-IN MICROVARADS
400V UNLESS OTHERWISE SPECIFIED
VOLAGES REFITIVE TO GROUND

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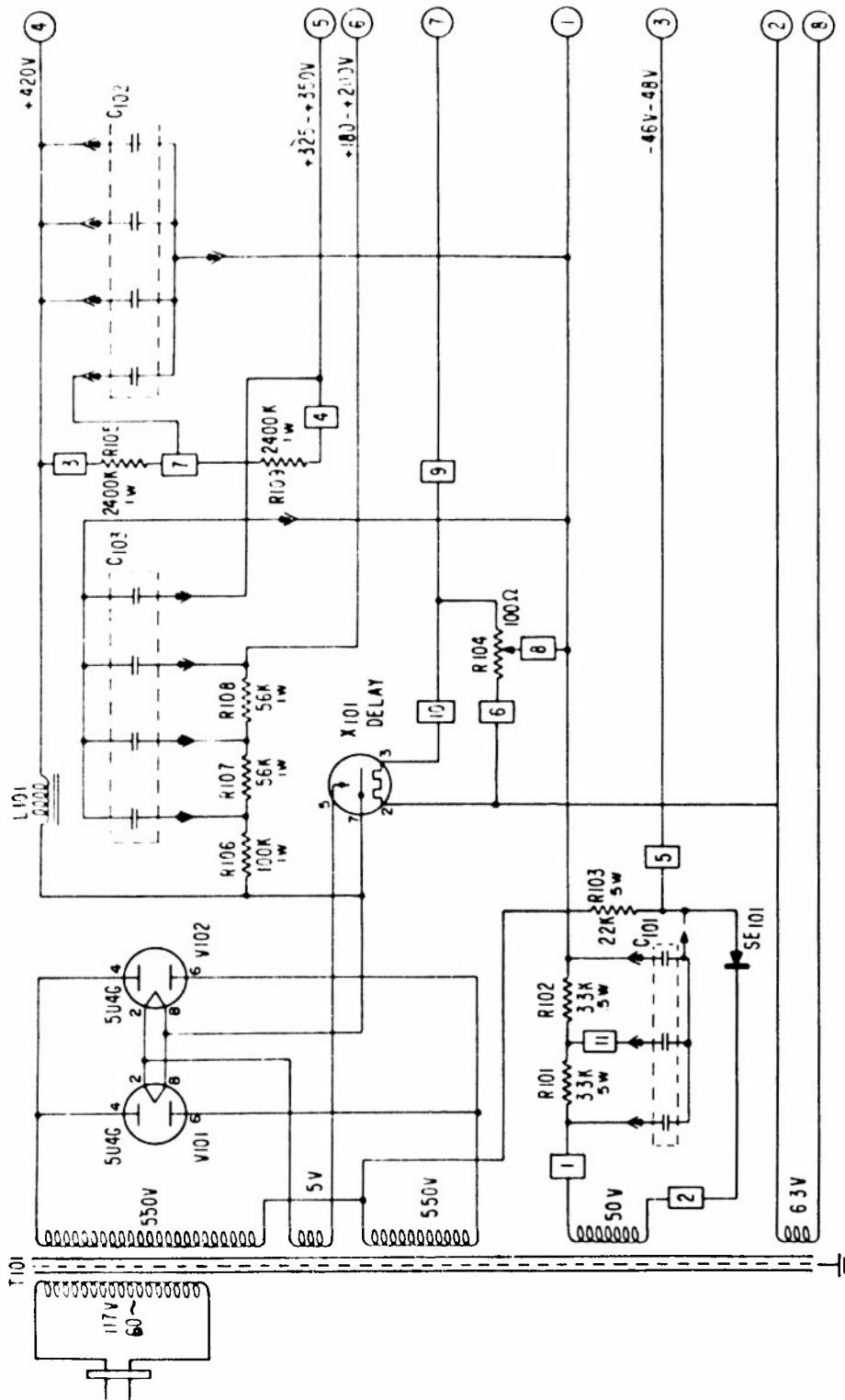


Figure 24 - McIntosh Model 50-W1 power supply

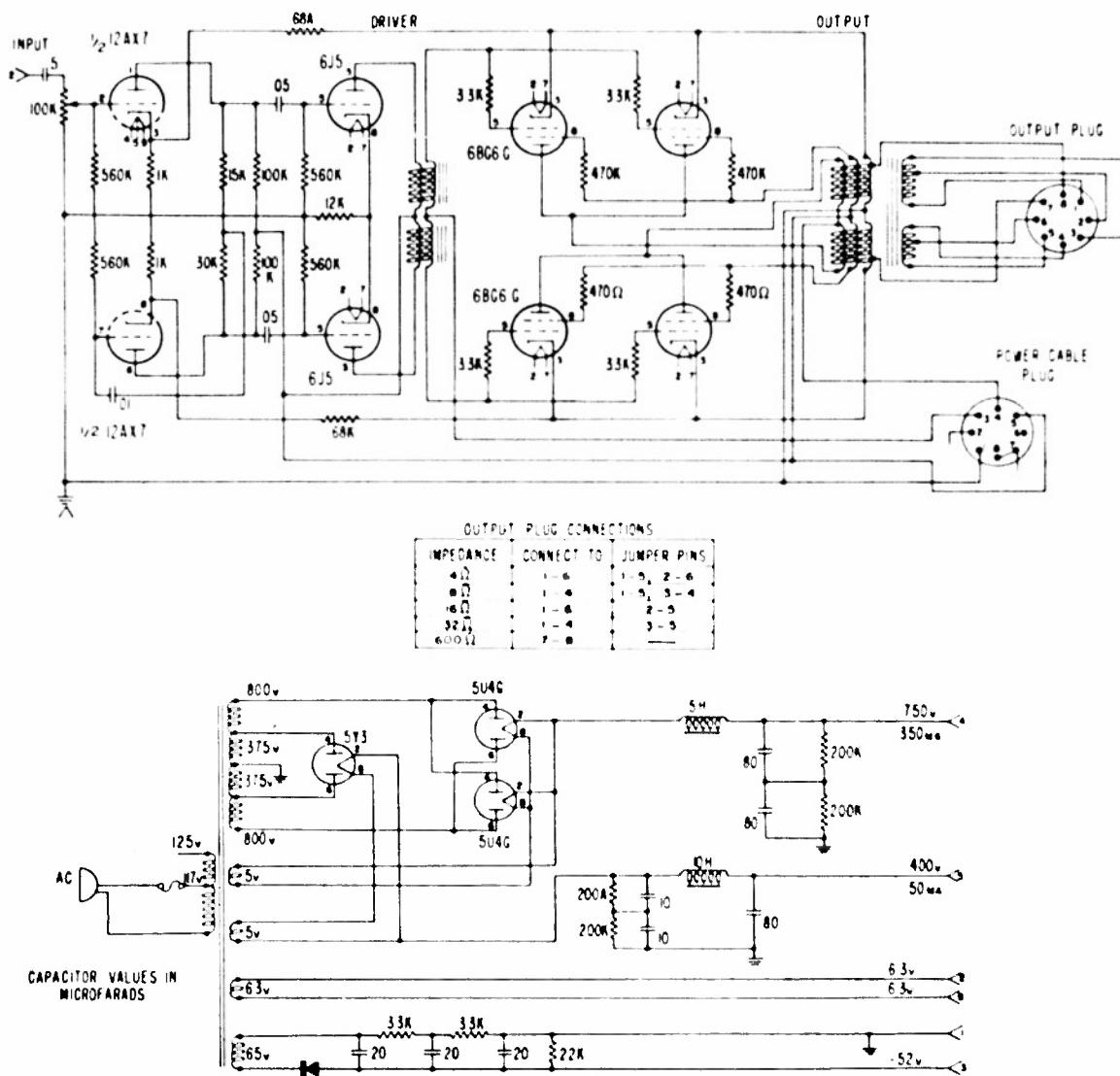


Figure 25 - McIntosh Model K-100

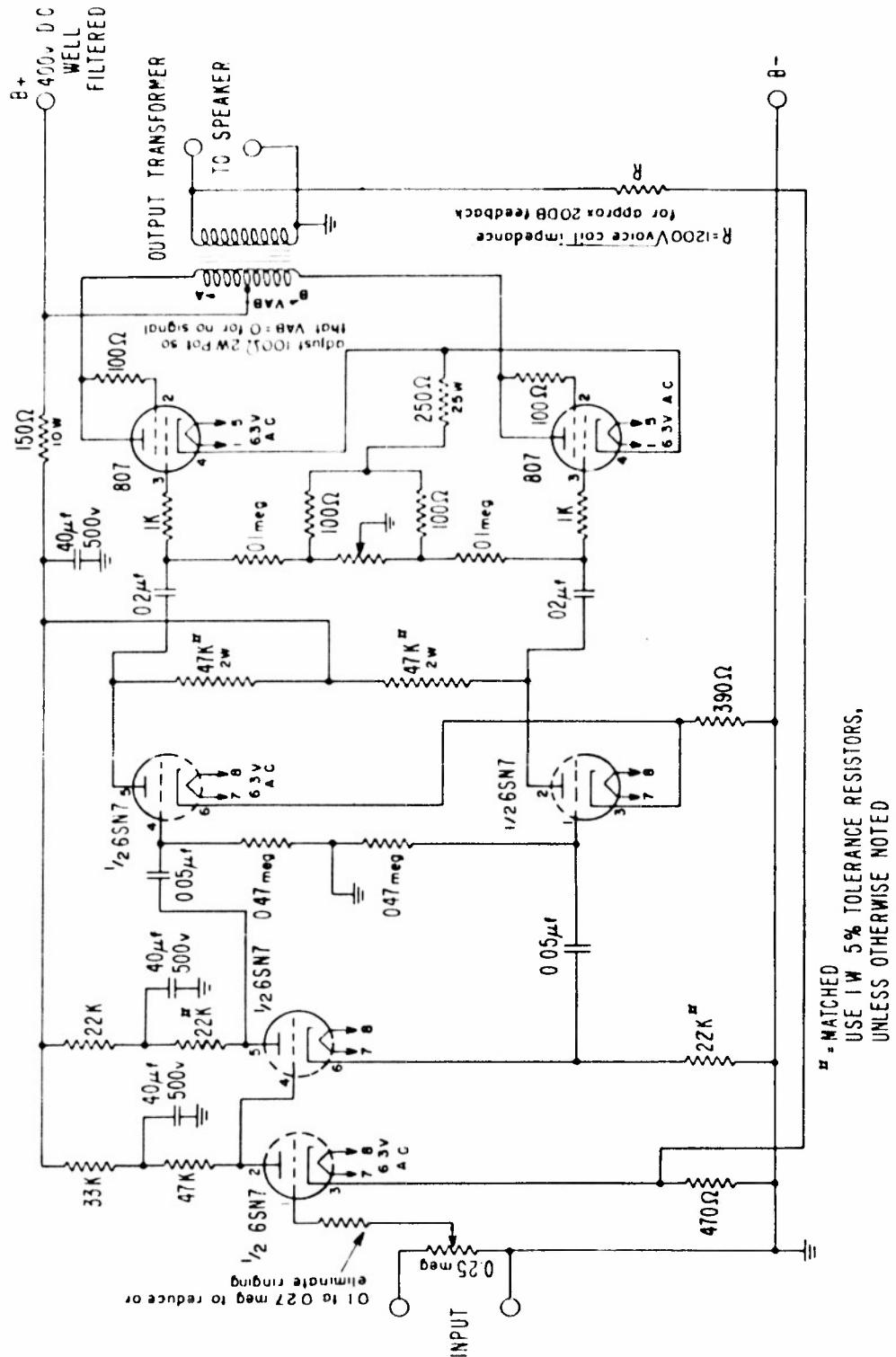


Figure 2b - Williamson circuit

WATCHED USE 1W 5% TOLERANCE RESISTORS,
UNLESS OTHERWISE NOTED

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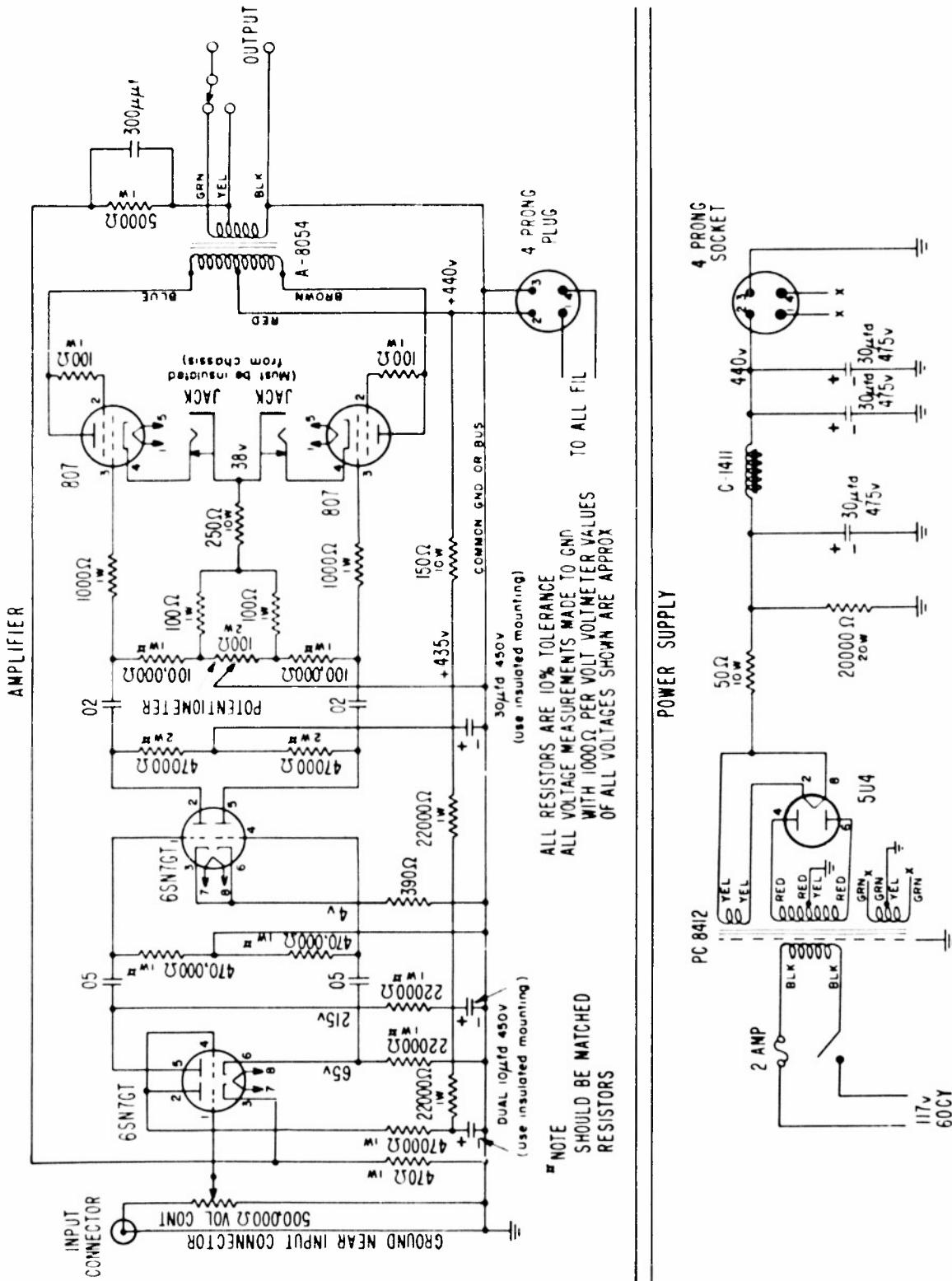


Figure 27 - Williamson circuit with Stancor A-8054 transformer

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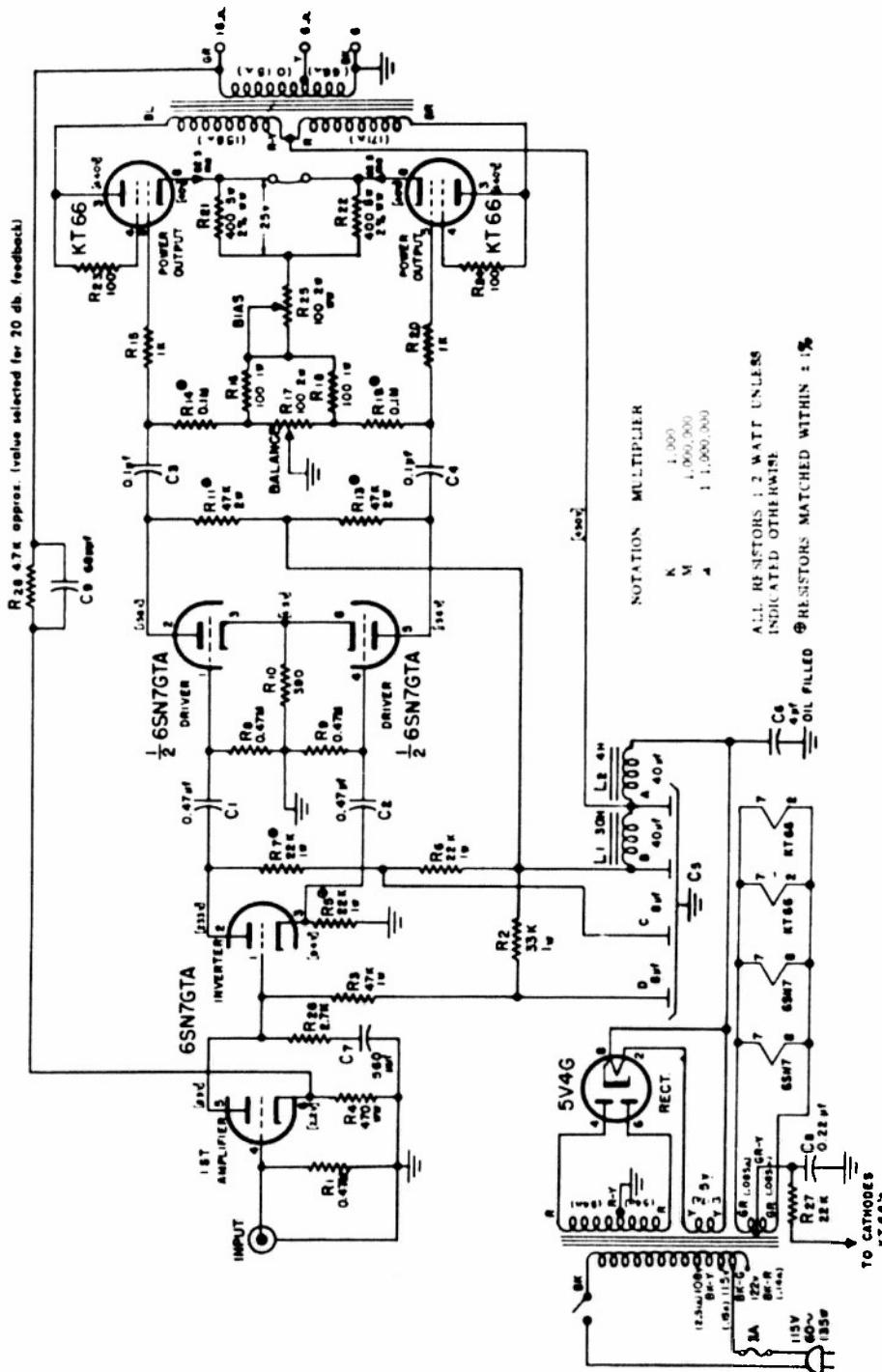


Figure 28 - Williamson circuit, Craftsmen Model 500

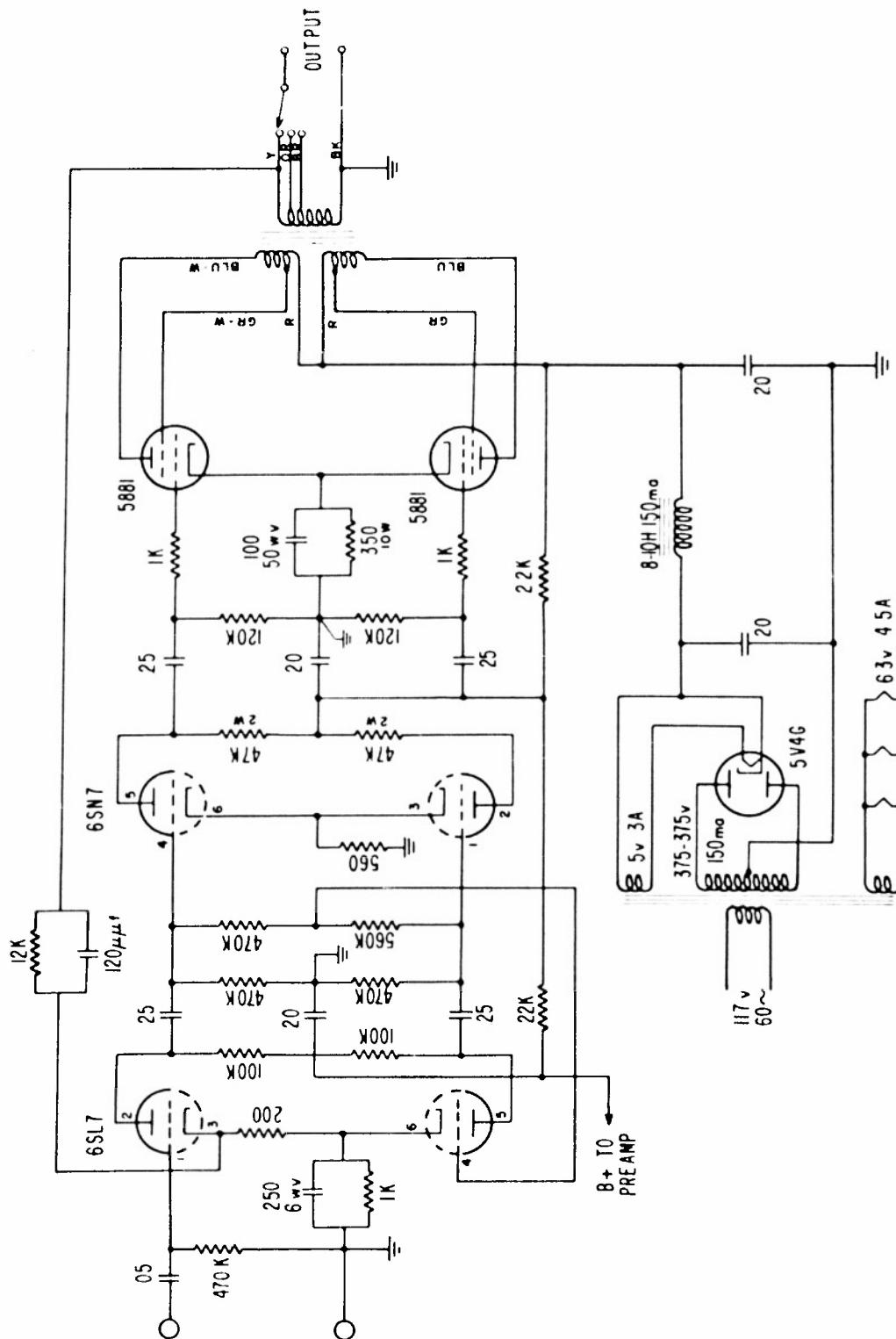


Figure 29 - "Ultra-Linear" circuit

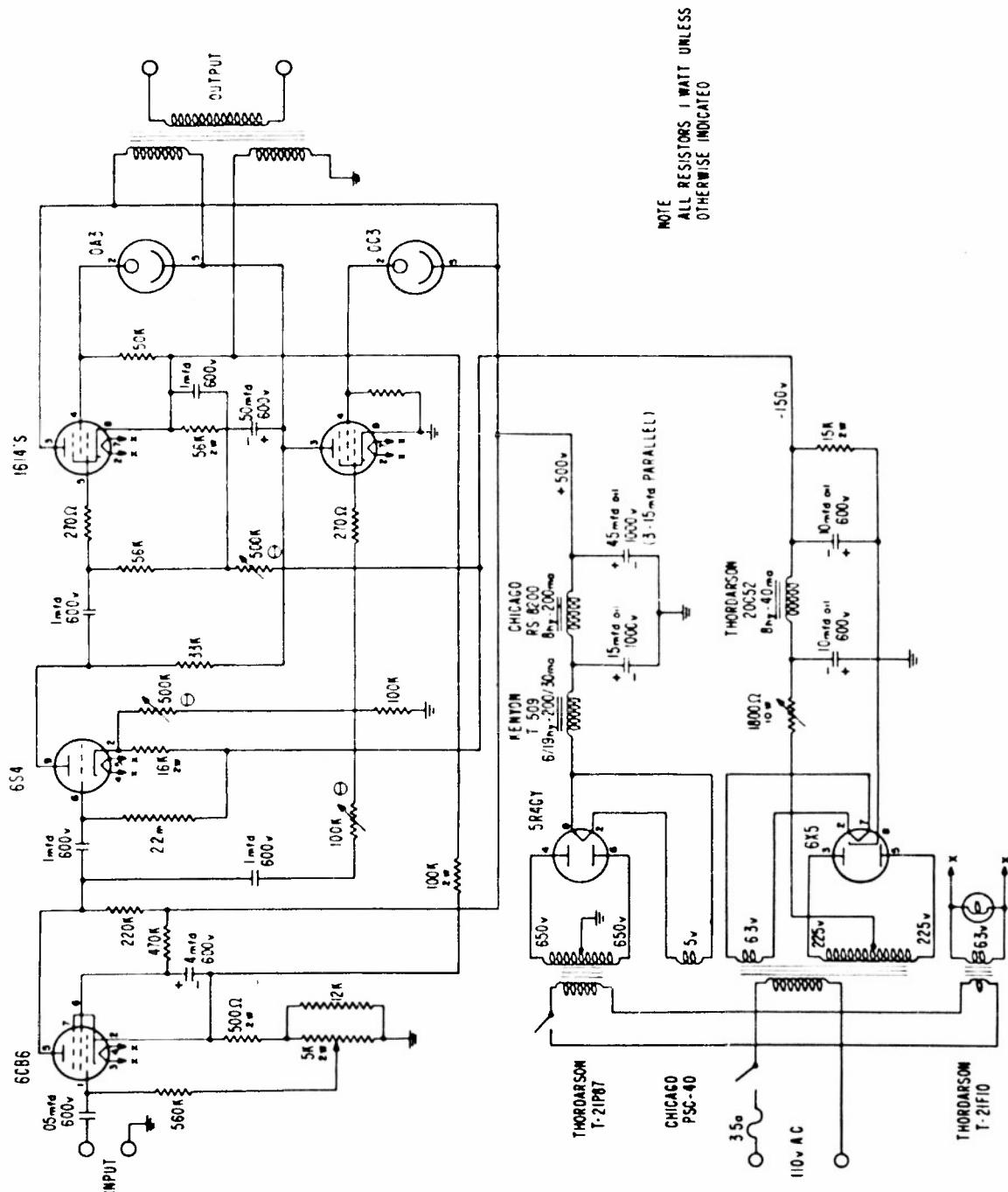


Figure 30 - General Radio single-ended, push-pull circuit

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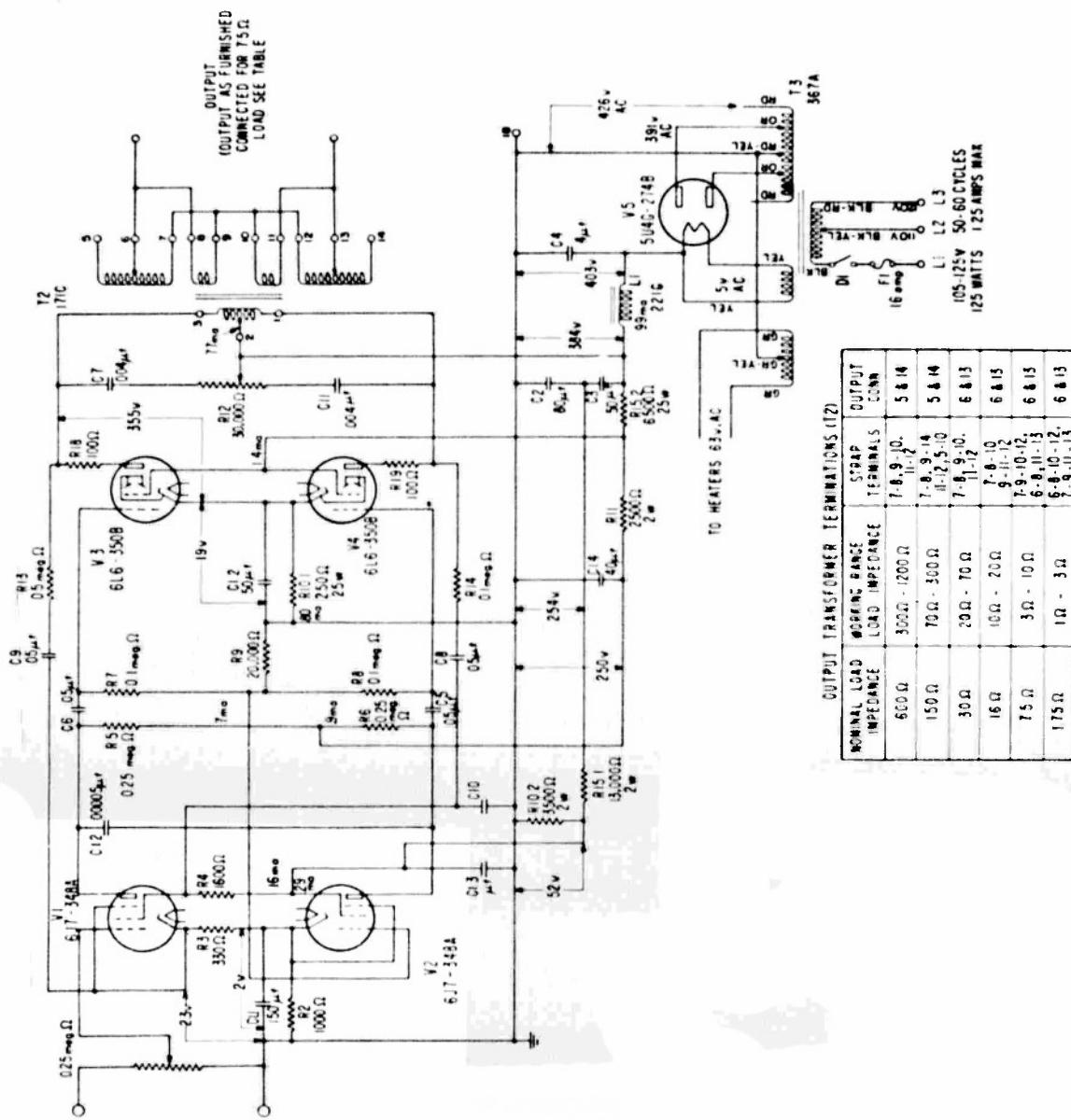


Figure 31 - Western Electric type 124 circuit

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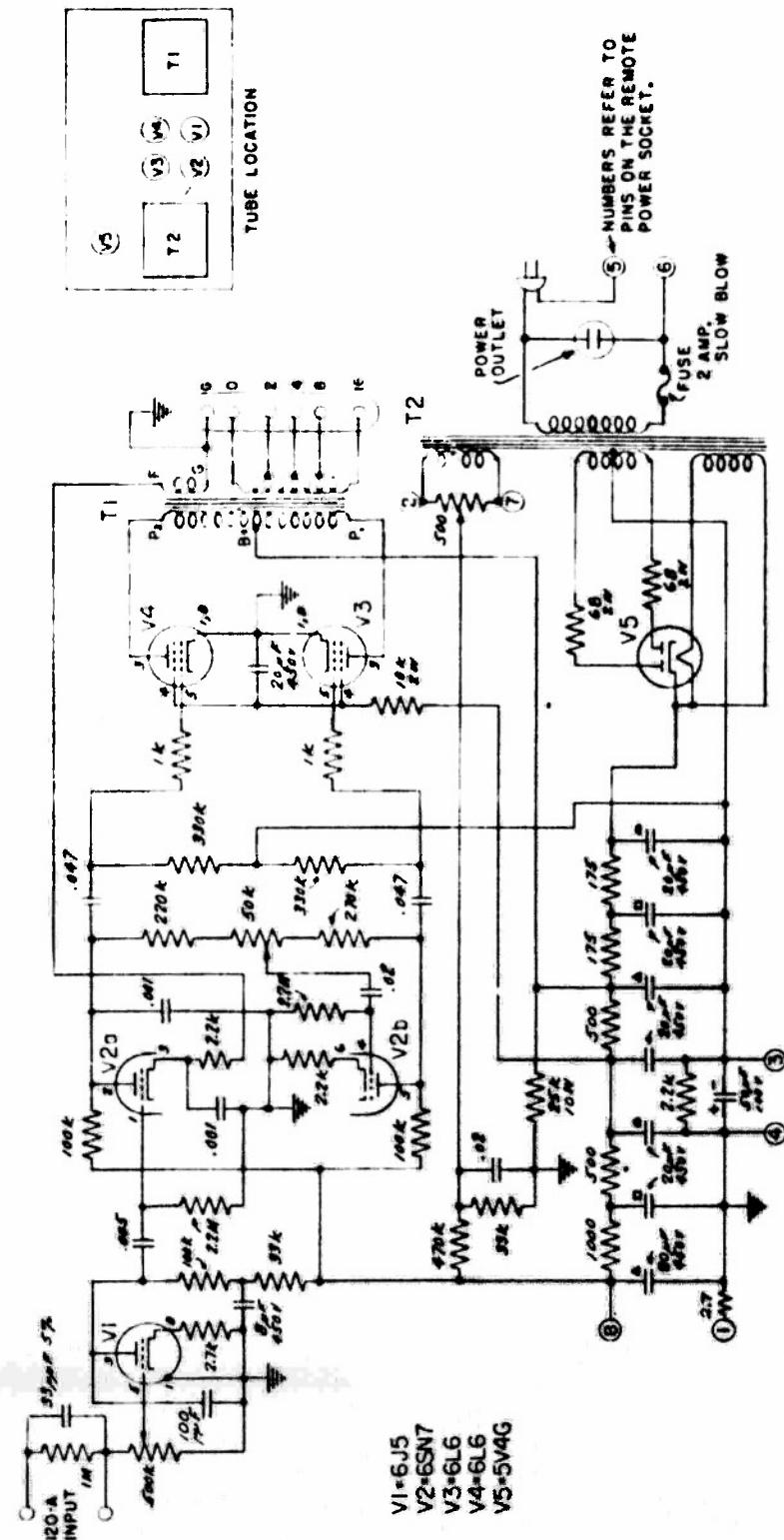


Figure 32 - H. H. Scott type 221-H

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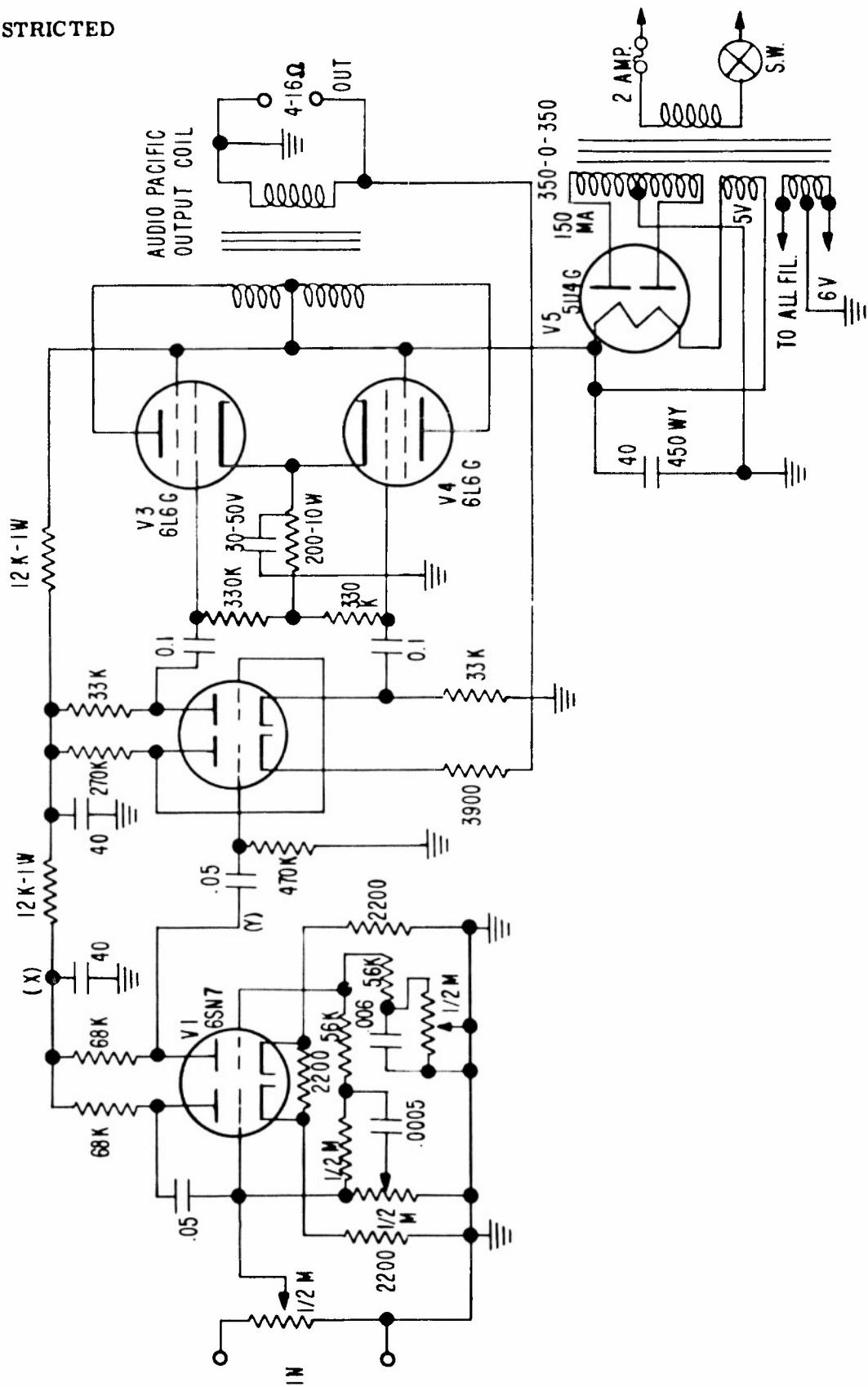


Figure 33 - Audio Pacific

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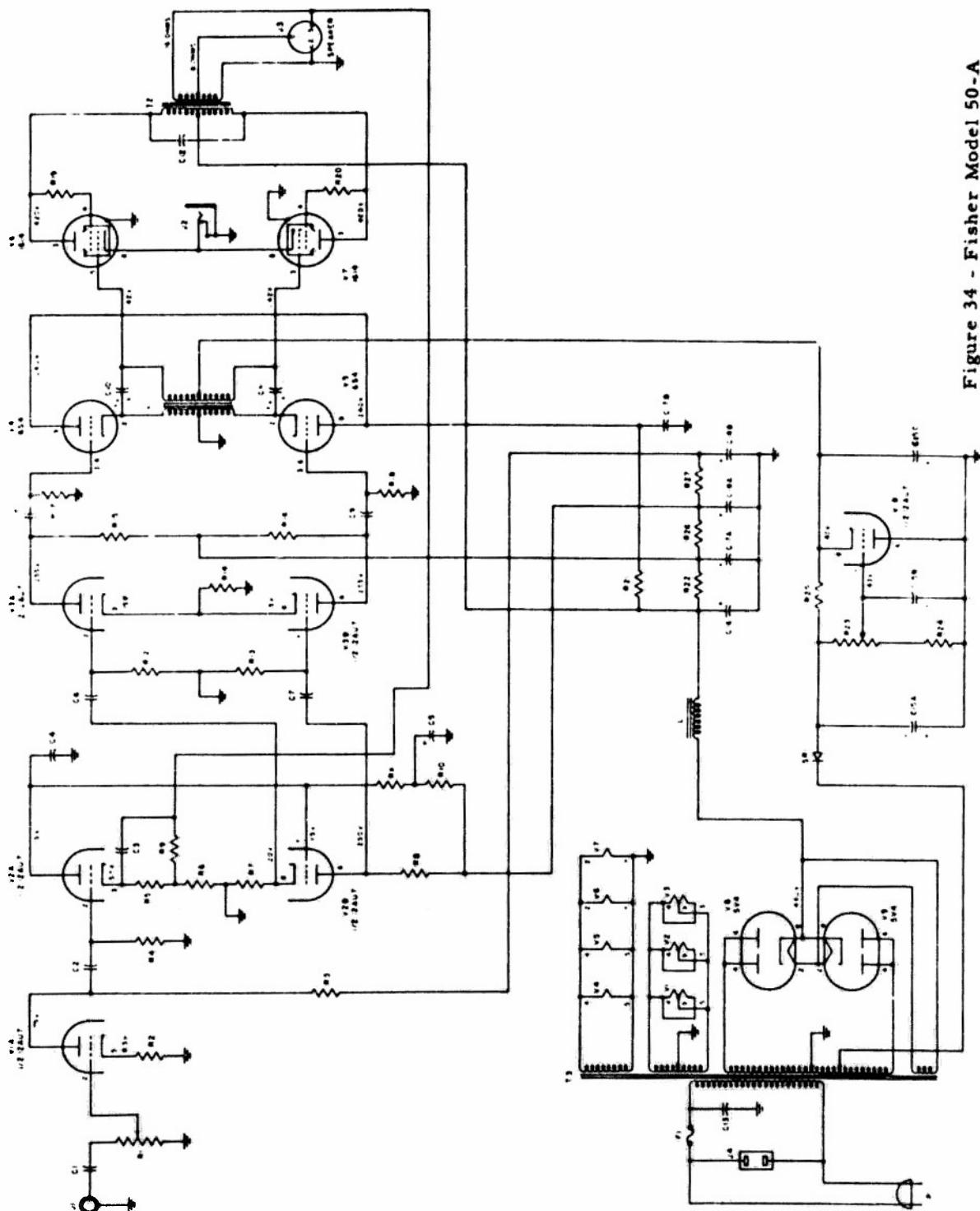


Figure 34 - Fisher Model 50-A